

## **California's Hydroelectric Resources: Development, Diversity, and Significance**

Presentation to the California Cooperative Snow Surveys Program  
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By Jim Woodward, Electricity Analysis Office  
California Energy Commission  
[jwoodwar@energy.state.ca.us](mailto:jwoodwar@energy.state.ca.us) phone: 916-654-5180

### **Biographical introduction:**

Our first speaker, Jim Woodward, has been with the California Energy Commission for 2 years as an energy analyst and forecaster. Before that, he did archeological and historical surveys for 25 years with State Parks, the US Forest Service, and a PG&E contractor. He's an active Scout leader for his son's troop, organizing outdoor adventures, a private pilot, and an avid skier.

### **PRESENTATION:**

1. Thank you. It's an honor and a privilege to be invited to join your conference and contribute to an excellent program.

When we say hydropower, for many people a picture of Hoover Dam comes to mind. So let's deal with that. Hoover Dam can generate 2,062 MW when Lake Mead is full. Peak energy production usually occurs from March to May, with over 500 million kilowatt hours a month. Hoover Dam was built first and foremost to control flooding on the Colorado. Regulation of river flows and water storage were secondary benefits after flood control was achieved.

2. Power plants were included mainly to repay the federal government for construction costs. This is an out-of-state resource, on the Arizona-Nevada border. Several cities in southern California own Hoover entitlements, as does Southern California Edison and Metropolitan Water District, adding up to 646 MW owned by California utilities. For several decades, this was the only significant source of electrical energy imported into California.
3. Edison was the first to study the hydroelectric potential of Boulder Canyon, as seen on the right in 1902. Engineer J.B. Lippincott was not enthusiastic. Quote, "The district in question ... is exceedingly remote ... as far as power consumption is concerned (there are) no towns. A power company to be successful would have to very liberally assist in the general development of the country before it would obtain substantial returns for its investment." Since Hoover dam was completed in 1936, ...

4. efforts to build nearby load have been rather successful. If you like what has developed there, be sure to give some credit to hydropower. If you don't like what you see, you can safely bet there was some other factor in play.
5. Farther down the Colorado River, the US Bureau of Reclamation built and operates Parker Dam, 108 MW, paid for almost entirely by the Metropolitan Water District of Southern California. MWD's pumps lift water 290 feet above Lake Havasu to begin a 250-mile journey west. At storage reservoirs and along the feeder lines, there are 15 small generators adding up to about 100 MW. But on the Colorado Aqueduct, pumping load greatly exceeds the re-capture of energy from falling water.
6. California now takes 5.5 million acre feet a year from the Colorado, quite a bit more than our rights to take 4.4. Imperial Irrigation District diverts over 3 million acre feet at Imperial Dam near Yuma. It flows through the All American Canal, which includes 8 so-called run-of-river plants with a total capacity of 85 MW. The stability of Salton Sea depends on continuing inputs of agricultural drainage. The water and power operations are clearly sustainable, but as salts accumulate in Salton Sea, there's no agreement on how to perpetuate this accidental oasis for the long term.
7. The other great gravity-powered aqueduct in California delivers water from the Owens Valley to Los Angeles. In 1913, construction of the first Los Angeles aqueduct was underway. This is looking north between Olancho and Lone Pine, with the Alabama Hills on the left. In the long-term desiccation of Owens Dry Lake, partly shown in the lower right, this was the last straw. The hydro industry likes to say that all hydropower is renewable and emissions free, which is physically true for the generation sites. However, dust storms that begin at Owens Dry Lake have been the source of up to 40% of the nation's airborne particulates. Fortunately, some successful abatement programs by LADWP are now underway.
8. The City of LA successfully tapped 4 of the 5 streams that flowed into Mono Lake. The Lee Vining Conduit takes water from Rush Creek to Grant Lake, and from there, the Mono Craters Tunnel heads SE. The water is made to work as it falls, passing through the Upper, Middle, and Control Gorge plants, each about 38 MW.
9. There are 14 hydroelectric plants along the route, with a total capacity of 269 MW. Eight of the plants are smaller than 10 MW, including Cottonwood and Haiwee as the aqueduct keeps to a grade above Owens Lake. Under the

peculiarities of state law, only generating plants smaller than 30 MW, nameplate, are counted as “eligible renewable energy resources”.

10. The largest plant in the LADWP system is San Francisquito No. 1, 75 MW, built between 1913 and 1917. The pictures show 1924 and 1982. Abundant water was a necessary ingredient for the development and growth of LA. I would add that roughly 50% of all hydro plants over 5 MW provide ancillary services, such as spinning reserves, which can be a very profitable to owners, and an important contribution to the grid.
11. Now to the Sierra Nevada. In 1913, Congress allowed Hetch Hetchy *and* Lake Eleanor to be built within Yosemite National Park. An aqueduct system sends water west for 167 miles, including passage through 4 powerhouses. Two different tunnels lead to the Kirkwood powerhouse, rated 114 MW.
12. The next big drop is to Moccasin powerhouse, with 119 MW. From there the water goes under New Don Pedro reservoir. Former mayor Dianne Feinstein, now our senior US Senator, has called the system San Francisco’s “birthright”.
13. The water *is* essential to San Francisco and the peninsula, but the city’s power lines only made it to Hayward. Water and power lines the cross the central valley in an area just peripheral to the Delta. The electrical system has provided a wealth of revenue for municipal programs, though over \$2 billion in maintenance on the system has been deferred. Last November, a break in the underground pipe near Ripon cut water deliveries in half for a while.
14. Shasta Dam, with 625 MW, is the largest generator in the Central Valley Project. The dam has recently been retrofitted to allow for temperature controlled release of water from various depths, in hopes of improving salmonid habitat.
15. USBR is the best dam operator in California in making their hydro operations transparent. On the left is a graph of water releases for 24 hours, last December 2<sup>nd</sup> the 3<sup>rd</sup>, a random choice. At 7 am, water releases ramped up quickly to 10,000 cubic feet per second, and stayed there until noon. Then discharge went down to 2,100 cfs until 3 pm, and was back up to 10,000 cfs during hours 16 to 22. After 1 am to 6 am, discharge was close to zero. The right side shows pretty much the same pattern for 7 days in early December. On weekdays there’s a mid-morning peak of 5,000 to 6,000 cfs, followed by a mid-day lull. Saturday and Sunday mornings ramp up slowly, following load without a mid-morning peak. PG&E has the contract rights to integrate the energy from all Central Valley Project dams, including some flexibility in

dispatch, I'm told. As Tom Patton mentioned earlier today, that contract expires at the end of next year.

16. As we all know, one has to have fuel water to have dispatch. Hydro is an energy limited resource. In February 1983, a wet year, Folsom was spinning out 200 MW, in big contrast to August 1990 when most of the lakebed was dry. Folsom was authorized in 1944, and completed in 1956 ostensibly to provide 500-year flood protection.
17. This was the site of San Luis Reservoir in 1965, and afterwards with 2 million acre feet. The turbines at Gianelli, between San Luis Reservoir and O'Neill forebay, do double duty: pumping water in off-peak hours, and generating up to 421 MW to help meet daytime loads. The federal turbines at San Luis pump water up to O'Neill from the Delta Mendota Canal. During irrigation season, they spin in reverse, generating 25 MW, but it's not the same as daily pumped storage.
18. The east branch of the California Aqueduct ends at Lake Perris, shown here on a remarkably clear day, a man-made lake on a former potato field. When water is released for distribution, it first goes through an 8 MW plant. Generating resources like these are not dispatchable, and don't provide ancillary services, but their output can be very predictable and reliable.
19. The vast majority of dams in California have been built without power plants, though some have been retrofitted to include this feature. La Grange Dam on the Tuolumne River was built in 1893. In 1924, a 4½ MW plant was added, fed by a short diversion tunnel from the dam.
20. Improvements to hydro facilities used to occur whenever engineering and economic studies matched up with financing. This is the main canal for Turlock Irrigation District, downstream from La Grange. The trestle over Morgan Gulch was later replaced by earth fill. Nowadays, it is common to defer major improvements in water delivery, energy efficiency, and environmental protection until the time a FERC license is renewed, which is every 30 or 50 years.
21. In the 1980s, Turlock ID added several small hydro plants to their canals, all of which the industry calls "run-of-river". 2 MW Hickman powerhouse was their first. The map shows Dawson 4 MW, Turlock Lake 3.3 MW, Hickman 1.1, Frankenheimer 4.7, Woodward (no relation) 2.3 MW, and farther south: Parker 2.8, Canal Creek .9, and Fairfield .9. The map shows neighboring South San Joaquin and Merced Irrigation Districts, but oddly does not show Modesto ID immediately north.

22. Turlock and Modesto irrigation districts have been feuding for decades, but occasionally they cooperate to get something built. This is a promotional brochure from 1910, courtesy of the California State Library. Borrowing money and building dams and canals was a big investment with big risks, especially in the early years with a shortage of paying customers and inadequate metering. On the right is Turlock Lake. To the left of the lake, you can still see hydraulic dredger tailings in the river bed of the Tuolumne.
23. This is SMUD territory: a full Union Valley reservoir in June 1971 on the left, and the record drought year on the right: August 1977. Even in a near-average year, SMUD has very little carryover storage in its hydro system. Total reservoir storage on the American River is only equal to 54% of its average runoff. That compares to 250% on the Stanislaus storage to runoff, and over 400% on the Colorado.
24. Here we're looking west to Union Valley from Desolation Wilderness above Wrights Lake. Water from this part of the Crystal Range flows down through Wrights Lake, to Ice House reservoir, then by tunnel to Jones Fork 11 MW, into Union Valley reservoir and its 47 MW powerhouse, then to Little Junction Reservoir, then by tunnel to Jaybird 144 MW, then into the South Fork American River to Slab Creek, where it is either diverted by tunnel to White Rock PH 224 MW, or re-released into the river channel through 0.4 MW Slab Creek. After all that, it will go through PG&E's 7 MW Chili Bar, and then through USBR's plants at Folsom and Nimbus. This is a simple staircase compared to others!
25. In southern California, construction of small hydroelectric plants began in 1886. One of Edison's oldest powerhouses is the Sierra plant, shown on the left, which is actually in the San Gabriel Mountains, built in 1901 and outside of FERC jurisdiction. The first 4 MW plant on the Santa Ana River was built in 1899, including an 83-mile transmission line to Los Angeles carrying from 33,000 volts, a world record at that time.
26. This is Rush Creek powerhouse, on the east side of the Sierra about 1923. When a streamflow is diverted into a flume, tunnel, or pipeline, it creates what is called a "bypass reach." In California, there are hundreds of miles of bypass reaches that may have very minimal continuing flows. The fuel is not consumed during generation—not one molecule of water is harmed going through the turbines—but the quality of water when it is returned to the stream is sometimes impaired, or perhaps more impaired [as judged by water temperatures and dissolved gasses].

27. Some hydro plants, large and small, continue to be important for local reliability, especially in rural and remote areas. The Bishop hydro plants provided Tonopah, Nevada with its first electricity in 1905. A lighting district formed, helping several local businesses.
28. The big producers for Edison are at Big Creek in the San Joaquin River watershed. Hydro plants are highly efficient at converting kinetic to electrical energy, with a normal ratio of 85 to 90%, much higher than thermal plants that top out at around 54% efficiency.
29. Huntington and Shaver Lakes had served as millponds. For hydropower, the dams had to be raised. The lake was then made accessible to the recreating public, not by car, but by the San Joaquin and Eastern Railroad, built by Edison.
30. This is part of the Ward Tunnel from Florence Lake to Huntington Lake, over 20 miles long, as it was being dug in 1925. The labor, engineering, and capital invested decades ago is a sunk cost that still pays dividends today to owners and ratepayers. Very low operating and maintenance costs for hydro make it generally the lowest cost of all energy supplies, typically under \$10 per MWh.
31. Here's Big Creek No. 1 under construction in 1913. Hydro plants have a long life expectancy, well over 50 years. In California, the average age is now 40 years. Farmers may have been the biggest beneficiaries of early hydro on the Kaweah, the Tule, and the Kern. Electricity made groundwater pumping cheap and reliable, displacing windmills and opening new areas to farming. This is a pumping plant and orchard near Exeter in 1914.
32. These are landscape level effects that are mostly irreversible, such as leveling the land, eliminating vernal pools, and draining vast wetlands of "tulares". The building up of spring and summer agricultural loads was very important to the economic success of utilities in the early 20<sup>th</sup> century, because it complemented fall and winter demand in urban areas for lighting.
33. By 1895, the "hydroelectricity craze had swept California" according to the *San Francisco Call* newspaper. Dillon Point tower was built to carry 60,000 volts from the Yuba River across the Carquinez Strait, supplying power to the streetcars of Oakland.
34. Some watersheds have been extensively developed, such as the North Fork Feather River. This is PG&E's Caribou 1 powerhouse, built in 1921, 75 MW. [PG&E is one of about a half dozen utilities that do cloud seeding opportunistically.] On

the Feather River, it is believed that cloud seeding increases runoff by an impressive 7%.

35. Most of the water that lands above Lake Almanor [point] will pass through 9 different power plants. These are manageable links in a series that allow a plant such as Belden [point] to become fully dispatchable. All of Belden's 125 MW are turned off and on every day, almost instantly if needed to serve load. Belden is also called a "run of river" plant, because it has almost no storage of its own, just a tiny forebay above its penstock. But the term is misleading because its real importance is based on high reliability, firm dependable capacity, low cost, and flexibility in dispatch.
36. These graphics give a quick overview of PG&E's Hydroelectric System, the largest in California. PG&E has 68 powerhouses, with 110 generating units. PG&E manages 99 reservoirs, 174 dams, 184 miles of canals, 44 miles of flumes, 135 miles of tunnels, and 19 miles of penstock. Total nameplate capacity is 3,896 MW, but the State can only guess at what the dependable capacity is.
37. Each load serving entity can define dependable capacity its own way, such as what could be sustained for 6 hours, for 4 consecutive days, during August 1977 water conditions. This is Tiger Creek on the Mokelumne, another example of so-called run-of-the-river plants, and what most people picture when the term is heard.
38. Now we have a few charts. "Cumulative generation capacity in California" shows existing plants today by primary energy type and the decade when they came online. Hydro was a primary source of electric energy in the first four decades of the 20<sup>th</sup> century. [The chart does not show plants that have been retired or replaced, and there were many fueled by coal, oil and even wood.] Substantial growth of hydro capacity continued to increase each decade through the 1970s. Since 1990, only about 100 MW of new hydro capacity has been added in California. The figure on the right shows Dependable Hydro Capacity, in light purple, and average spring runoff in magenta. Among all California Rivers, the Kings River has the most generating capacity. That includes PG&E's pumped-storage project at Helms, which is 1,212 MW. Next in total capacity is the Feather River, followed by the Upper Sacramento, the upper San Joaquin, American, Stanislaus, Tuolumne, Yuba, Trinity, Owens, and Mokelumne rivers. If anyone would like a copy of these charts, I'll gladly trade a business card for an email (see Thumbnail 13, 14).
39. The next chart, on the left, shows the "Sources of California Electrical Energy Consumption" since 1983. In-state hydro sources are in dark blue, at the

bottom. Hydro energy provided as much as 29% of the statewide total in 1983, a wet year, and as little as 9% of the total in 1992, a drought year. The average contribution of in-state hydroelectric energy has been 15% of all load. Average hydro energy production for the last 20 years has been just over 37, 000 GWh.

The most interesting chart today is the one on the right. You can see that total hydro generation varies with total Central Valley runoff, as you would expect. But the correlation is not exact. In the wettest years, 1983 and 1995, installed capacity was not adequate to use all available runoff, and some water was spilled to maintain flood protection. The changes move together, in the same direction, *except* in calendar year 1997, which began with a flood. Warm rains fell on a big wet snowpack, causing early runoff and a drop in generation that year (See Thumbnail 15, 16).

40. Everyone here knows the 10 hydrologic regions as defined by DWR. Within each region, we see—in orange, the middle bar, average yearly precipitation in million acre feet. The average runoff in each region is the bar on the right in purple, also in million acre feet. The blue bar, on the left, shows dependable capacity, times 100. So the Sacramento River region has over 5,700 MW, fueled by 52 maf of precip and 22 maf of runoff. The San Joaquin basin has over 4,000 MW, making much more efficient use of 7.9 maf of average runoff. The third biggest region of the “big 3” for energy production is Tulare Lake basin, with 1,800 MW fed by an average 3 maf runoff. When generating capacity in blue is compared to average runoff in orange, it’s clear that Tulare Lake basin has the most intensively developed resources, followed by the San Joaquin, and then the Sacramento. The San Francisco Bay and Central Coast regions have practically no hydroelectric capacity.

Above the bar graph is a figure in red showing water year precipitation in 2003 through May 1<sup>st</sup>. [Where rain falls is obviously important.] Rainfall on the North Coast was 125% of average, but it doesn’t help statewide energy supplies that much, because only the Klamath, the Trinity, and the South Fork Eel have any significant capacity (See Thumbnail 17).

41. One of the great things about hydro forecasting is that no one expects you to be exactly right. We track the runoff forecasts that DWR provides for 13 rivers in the Sierra and Southern Cascades. We also do statewide energy prognostications based on the detailed runoff forecasts in Bulletin 120, with lots of help from confidential utility forecasts, which we greatly appreciate, with special thanks to Dr. Jan Grygier and PG&E.

Last year we predicted energy supplies would be 85% of average, and for 2002, actual generation was 84% of average. I must humbly note that several



complementary errors may be involved. For calendar year 2003, we estimated in May that in-state generation would be 108% of average, and it may be close to that or a little under.

42. On the left, we summarize the hydro universe as we know it and model it. Statewide there are 359 plants over one-tenth of a MW in size, with a total nameplate capacity of over 13,000 MW. Early in 2003, we contacted owners of the largest 235 hydro plants in California. We asked for detailed information on current infrastructure, historic generation, and for certain categories of environmental data, such as water flows. For us, this was an opportunity to acquire historical hydro data and improve our understanding of the hydroelectric generation system. The responses covered over 9,200 MW of capacity (See Thumbnail 18, 19).
43. Ownership of hydro capacity is shown on these two slides. On the left, PG&E is clearly the largest owner, followed by USBR, Edison, DWR, and SMUD. Some of the big plants with 2 owners are shown separately. On the left, the "other" category in green on the left is further broken out on the right slide, including Yuba County Water Agency, San Francisco, and Placer County (See Thumbnail 20, 21).
44. We asked managers to evaluate the relative importance of energy production high, medium, or low. Unfortunately, the owners of a majority of these plants chose not to answer this question. But overall, it's probably a fair sample based on a basically subjective evaluation at one moment in time. Energy was one of 8 functions that we asked owners to evaluate. The others are flood control, interbasin water diversion and storage, recreation, local water supply, navigation and rafting, fisheries, and all other environmental concerns. We also asked the owners to rank these purposes in relative order, 1 to 8 (See Thumbnail 22).
45. Based on those who did respond, Energy was the most important purpose for 70% of the plants in our survey (point-left). Flood control and consumptive water supplies are close together, but are well behind energy as the primary purpose. But when these answers are weighted by plant capacity, as shown on the right, energy production as the most important purpose drops to less about 40%, and flood control is a close second. Putting in another way, as power plant size increases, energy production is increasingly balanced by other demands and uses involving water (See Thumbnail 23, 24, 25).
46. Now on the left, we're looking at just Energy production. This shows how often Energy ranks as the number 1 purpose, about 40% of the time when the answers are weighted by plant capacity. It is surprising to some that some hydro plants

owned by public agencies *and utilities* are managed first and foremost to meet the biological opinion requirements of endangered species.

On the right, it appears that almost 90% of hydroelectric capacity is considered dispatchable, unlike geothermal which runs continuously as a baseload resource, and unlike wind and solar which are also intermittent, but are less predictable and not subject to flexible dispatch control that matches supply and demand.

47. Most of the public focus on energy supplies is rightly centered on how to meet peak load during a summer heat storm. Hydro resources are essential at that time, and the dry year minimum energy production numbers from 1977 are significantly less than average. Most of the reservoirs and power plants in the high country are managed by private and public utilities, and show less year-to-year variability in generation during the summer months. Big storage reservoirs in the lower elevations are mainly owned by State and federal agencies and irrigation districts, and show much more variation in energy output between wet and dry years (See Thumbnail 26).

48. The months of May and October show much more year-to-year variation in energy production, more than the summer months vary. These are two views of the high Sierra north of Whitney in May 1982 on the left, and November 1990 on the right. In wet years, the month of May can cause problems with too much generation. Transmission gets congested in places, and wholesale spot markets can reach zero dollars per MWh, which happened this year after the big storms in early May. After a dry year, fuel supplies may be exhausted by October. If cold weather comes before wet weather, this will drive up use of natural gas, the swing fuel for the state's power plants, reducing amounts of natural gas that go into storage for the winter, driving up gas prices.

49. Briefly, here is one more chart from our study. This bar graph shows amounts of plant capacity, and whether they are located on rivers that were historically accessible to anadromous fish. There are 92 plants with over 6,000 MW of capacity located on river reaches that were formerly used by salmon and steelhead. There are also 112 plants with 5,000 MW *not* located in this critical habitat. They may be on canals, or east of the Sierra, or in the high country, where freshwater fish species may still be affected. Most of the unknown category is due to uncertainties about what was accessible historically in the wettest years (See Thumbnail 27).

50. Throughout the summer, we import energy from the Pacific Northwest, where hydro comprises about 75% of that region's electricity supplies. This is Grand

Coulee, the largest hydro facility in the US at 6,800 MW, with 33 turbines in 3 powerhouses. On the right is a Flow Duration Curve for the Northwest Intertie, showing the top 100 hours in July in five different years from 1997. For hour one [point] when the most energy was flowing south on the tie, there is not much difference in capacity between the driest year, 2001, and the wettest years, 1999 and 1997. Hydro is an energy-limited resource, as noted earlier. Because of this, the dry year capacity declines more quickly going from left to right. This is the kind of information we're hoping to develop for California. What can we count on from hydro in the top 10 hours of our load duration curve to meet peak demand? Or the top 50 or the top 100 hours?

51. The era of building many large multipurpose dams in California is behind us. But large dams are still being planned and built elsewhere in the world, especially in China, which has the world's largest hydroelectric project on the mighty Yangtze. Just in the last century, floods on this river have killed roughly 300,000 people. The Communist Party leader on this project, Li Peng, said, quote, "The administration of a country's national affairs becomes easier when its rivers are tamed."
52. In June 2003, the gates were closed on Three Gorges dam. By 2009, it is supposed to generate 18,000 MW. Over a million people are being displaced, including boat trackers who pull vessels upstream along tributaries of the Yangtze. Boat trackers have worked this reach for thousands of years. We have seen social displacement like this in California, but on a much smaller scale. When Lake Berryessa filled in 1955, the farmers and ranchers received money for their land, but they never found another place to carry on that work. On the other hand, when LADWP bought up land and water rights in the Owens Valley, some of those farmers moved to the Imperial Valley and prospered. Some of their descendents who work the soil also inherited a distrust of big-city utilities, but they tend to take it out on Edison and the Met.
53. Before I took this job, I would marvel at scenes like this. Now, I see wasted energy, un-harnessed, and a terrible barrier for fish. There are many small barriers and waterfalls that are still passable to fish, though they face numerous mortal challenges in their struggle to reproduce. Our hope is to restore access wherever it is prudent and feasible, all over the map, tapping into the physical and financial resources that hydropower still provides.
54. Joan Didion wrote, "I know as well as the next person that there is considerable transcendent value in a river running wild and undimmed, a river running free over granite, but I have also lived beneath a river when it was running in flood, and gone without showers when it was running dry." Unquote. Much of the

infrastructure that supports hydropower is built to last a long time. It delivers low cost, reliable, renewable energy, with numerous environmental benefits and consequences, some of which we are only just now beginning to fully appreciate. Thank you.

**Cumulative Generating Capacity  
in California by Decade**

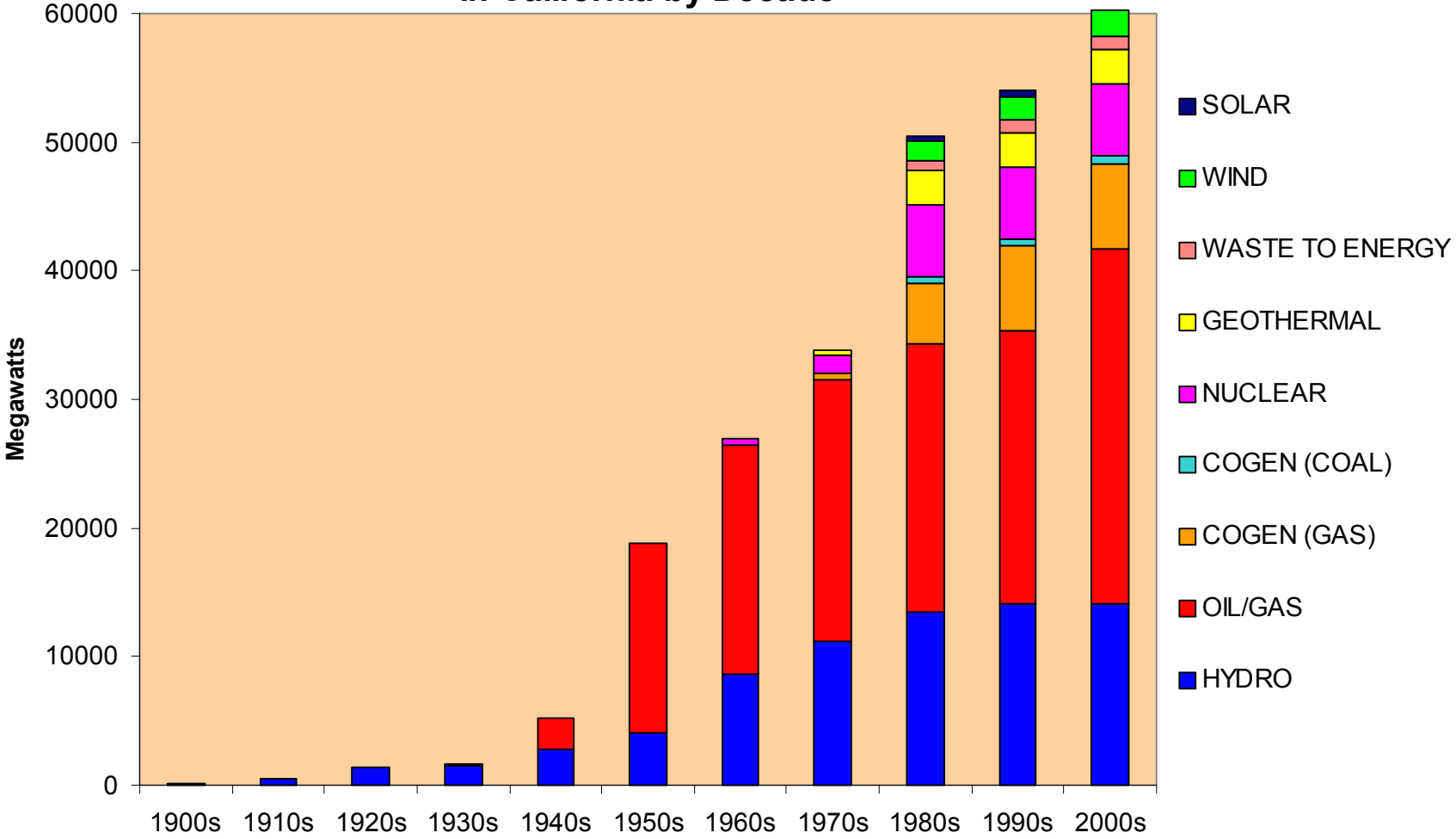
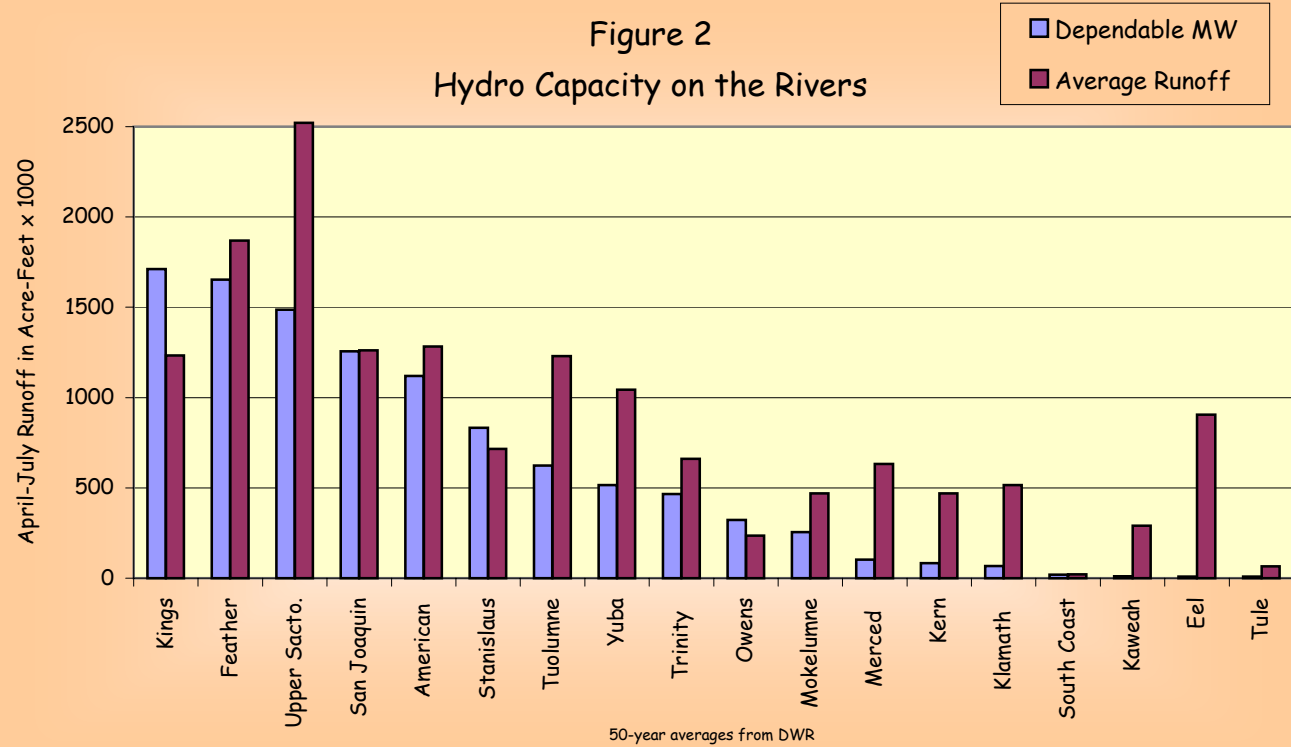


Figure 2  
Hydro Capacity on the Rivers



**Figure 3**  
**Sources of California Electrical Energy Consumption**

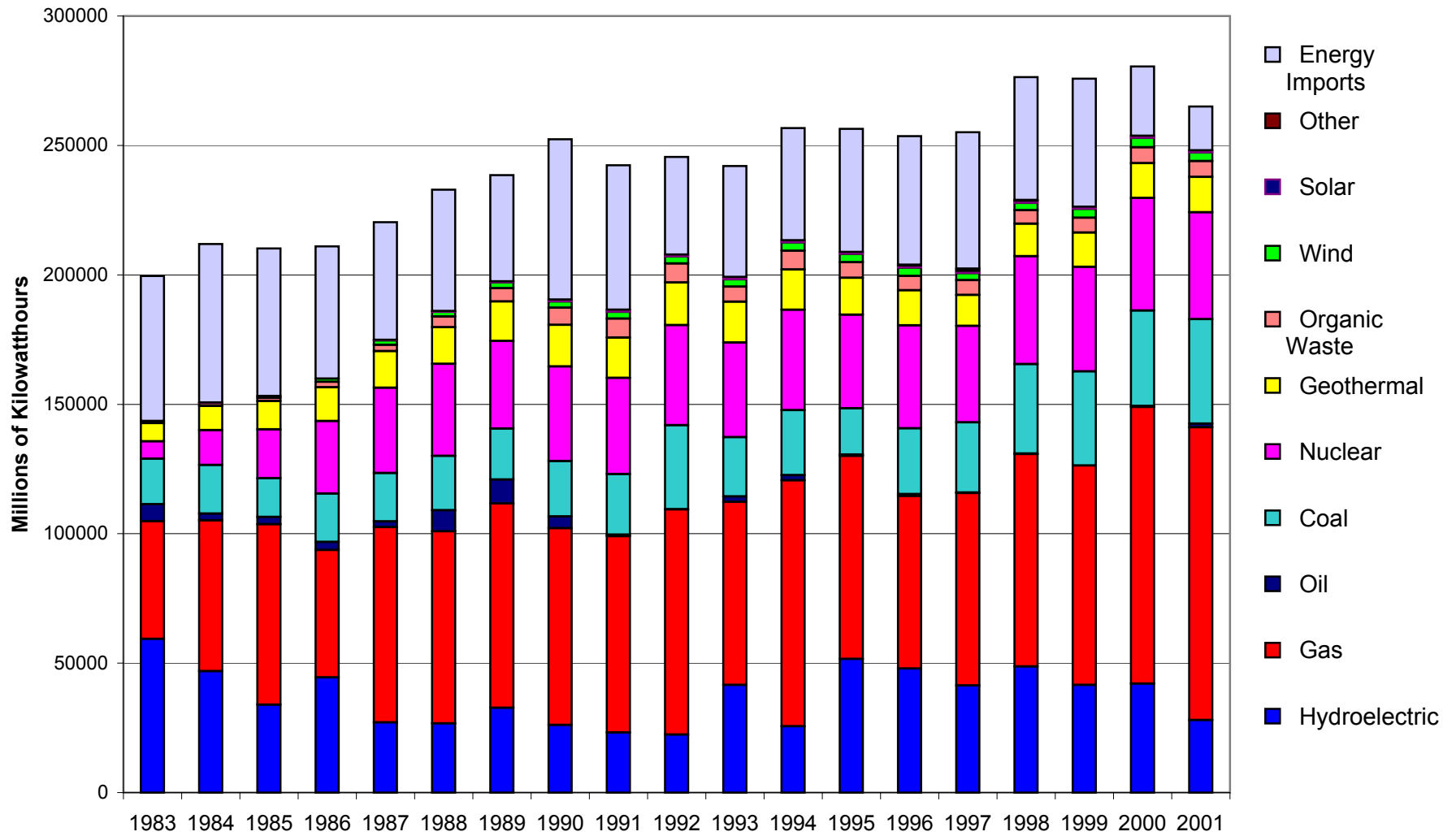
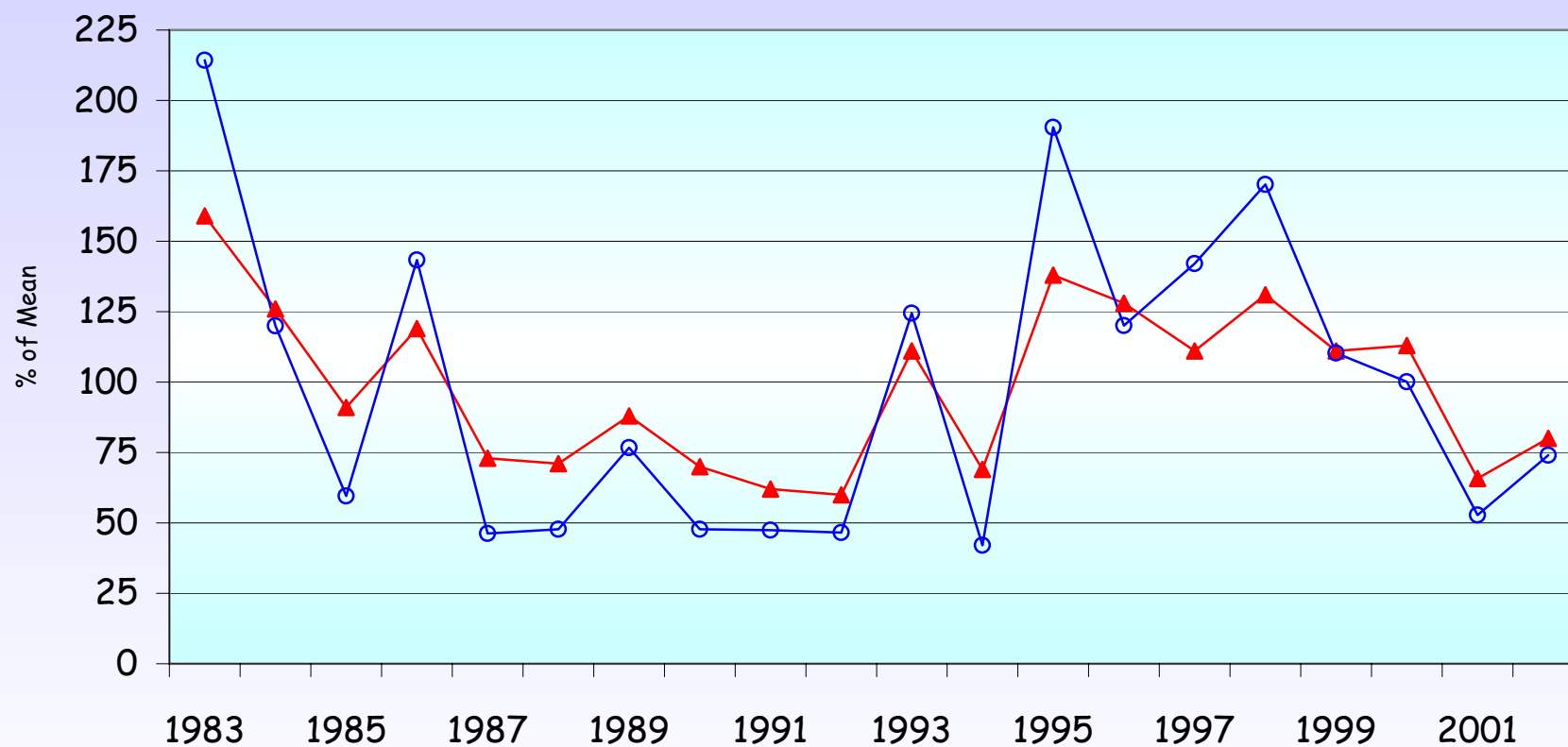


Figure 4  
HYDRO GENERATION &  
CENTRAL VALLEY RUNOFF

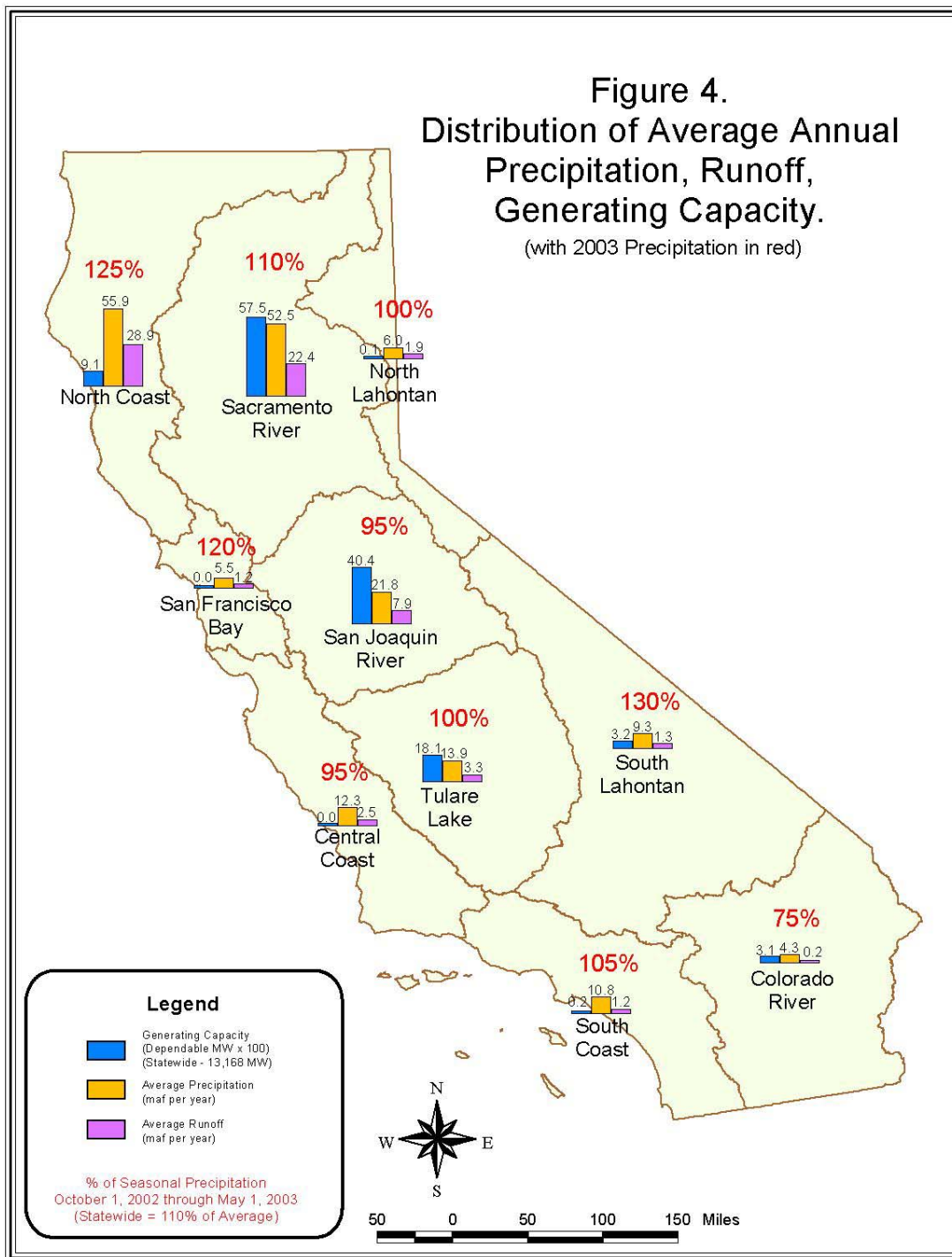
▲ Hydro Generation % of Mean  
○ Runoff % of Mean



From CEC Table J-11 & DWR Table WSIHIST

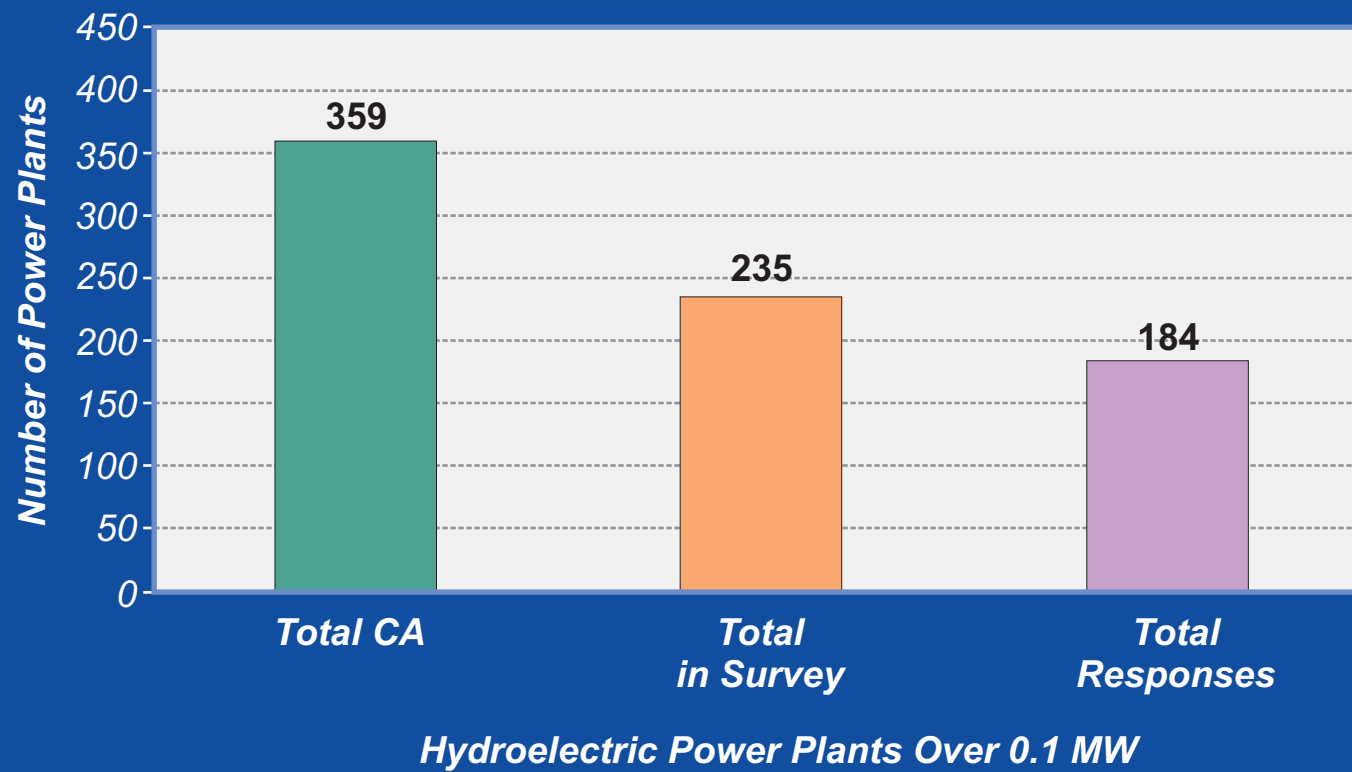


**Figure 4.**  
**Distribution of Average Annual**  
**Precipitation, Runoff,**  
**Generating Capacity.**  
 (with 2003 Precipitation in red)

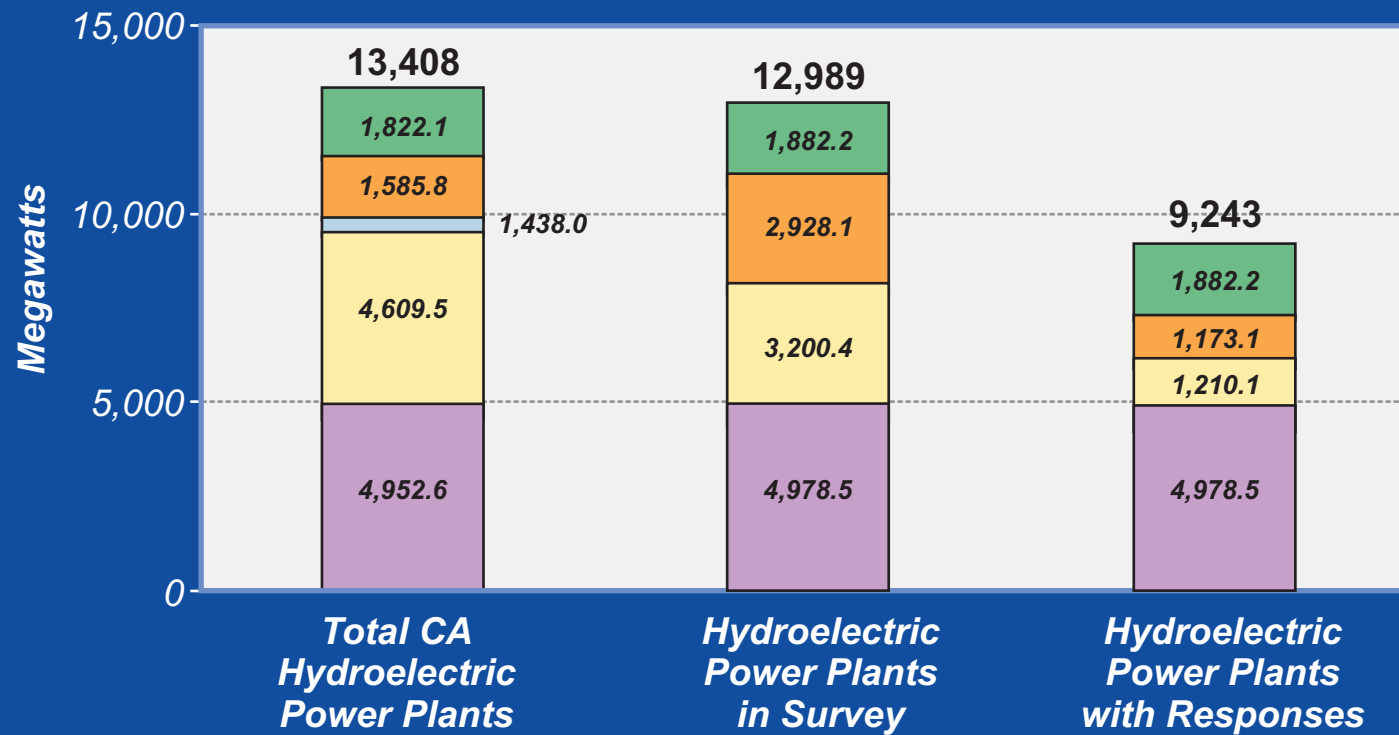


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## SUMMARY OF SURVEY RESPONSES

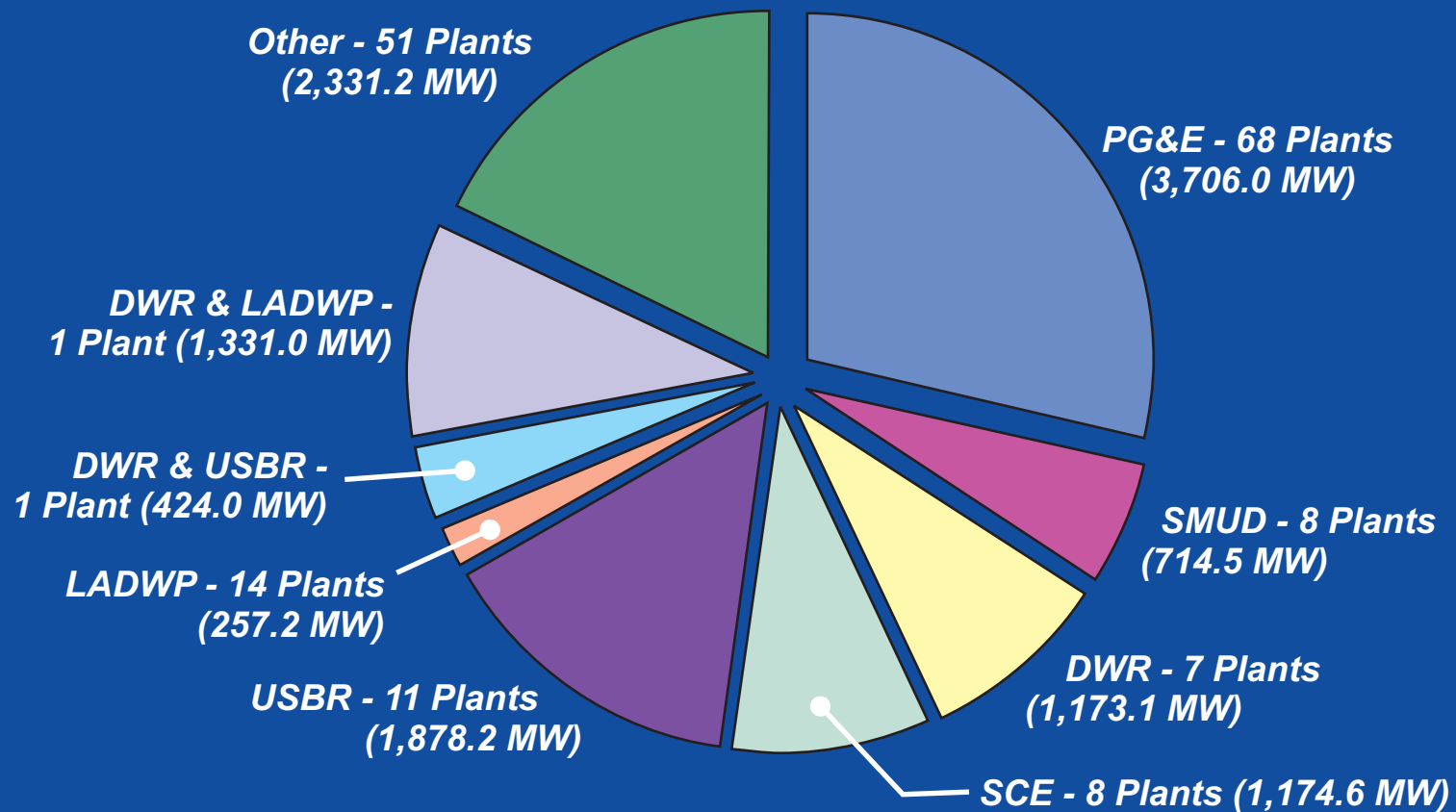


## MEGAWATTS BY HYDROELECTRIC OWNER

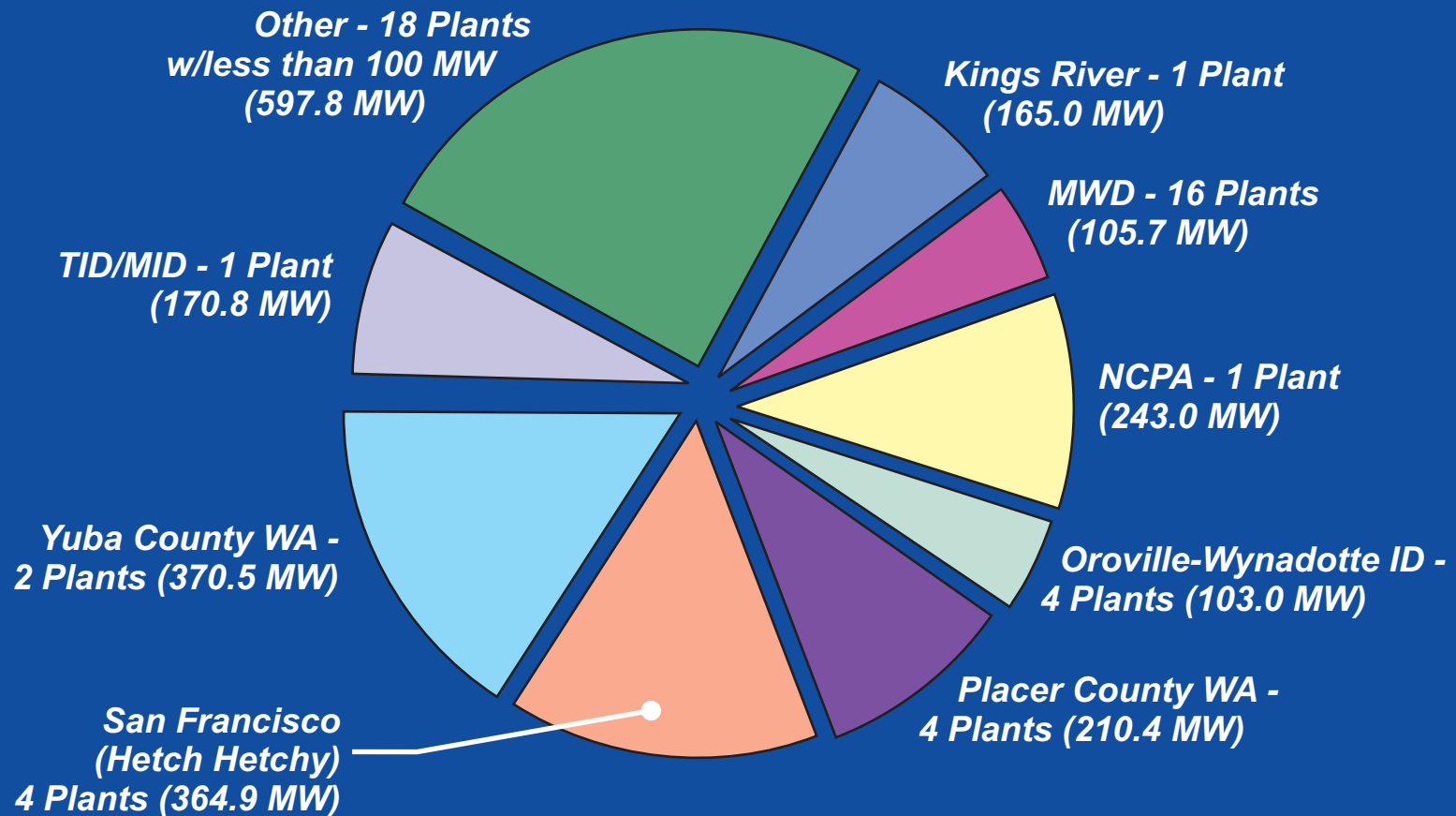


 Federal  State  Other  Municipal  IOU

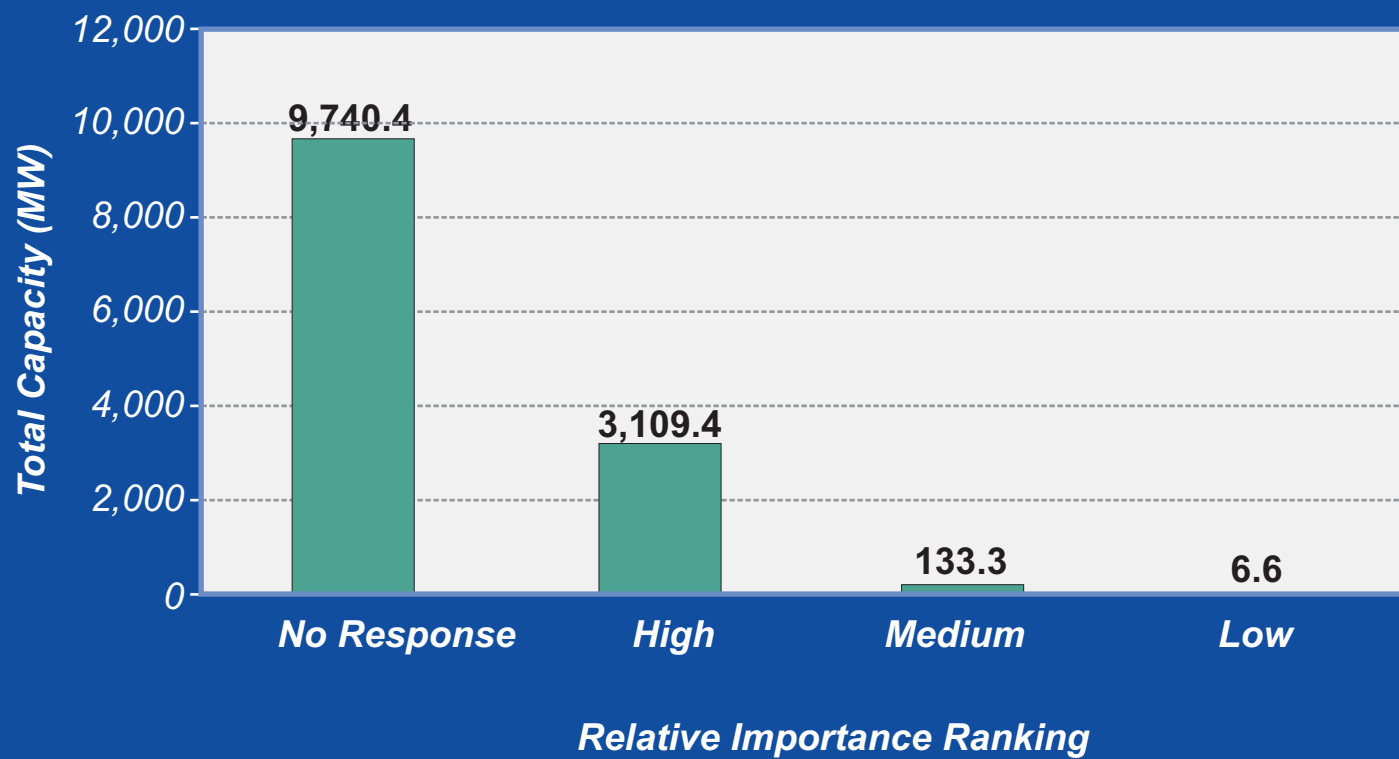
## POWER PLANT OWNERSHIP (by MW)



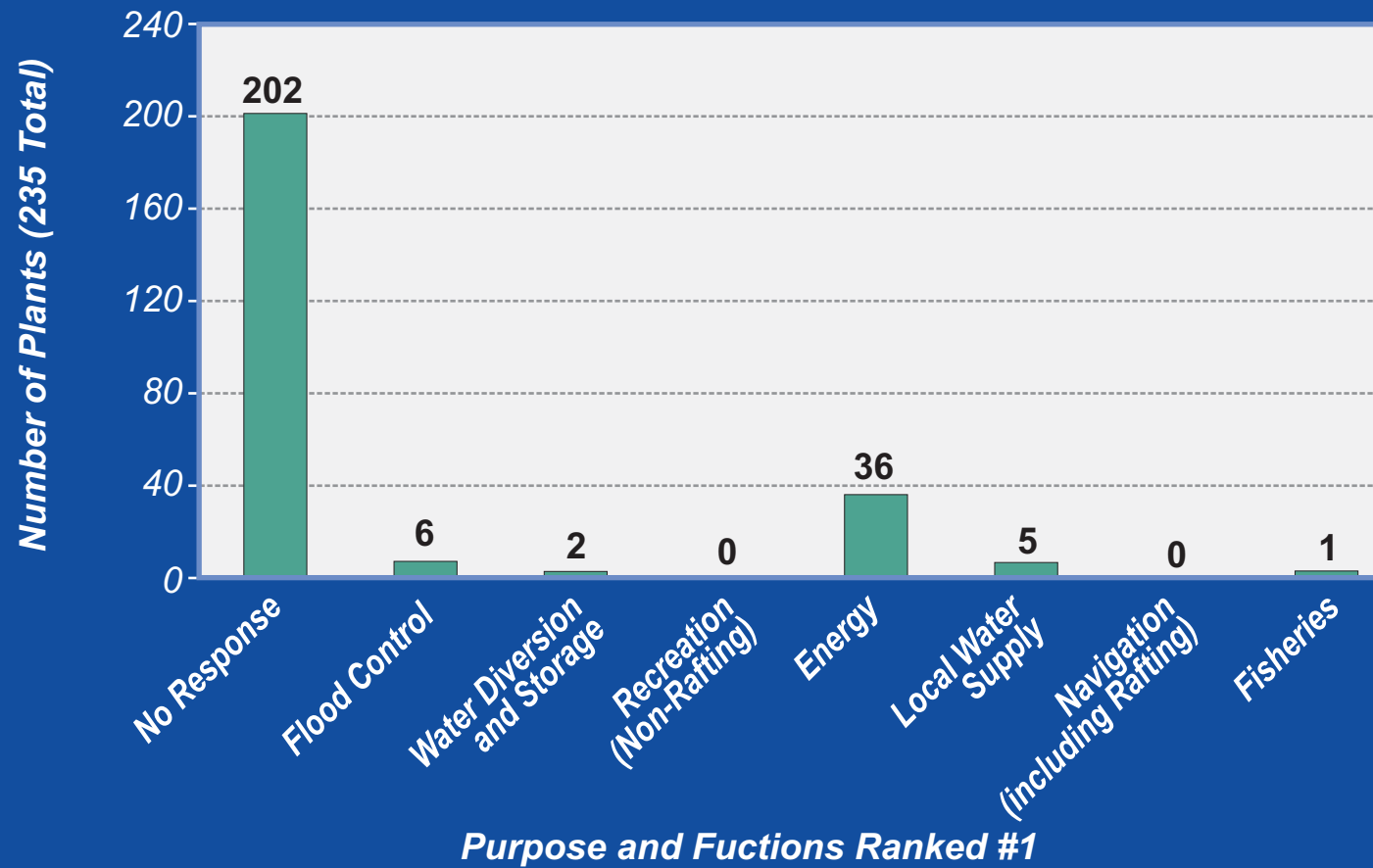
## OTHER POWER PLANT OWNERS (by MW)



## RELATIVE IMPORTANCE OF ENERGY PRODUCTION

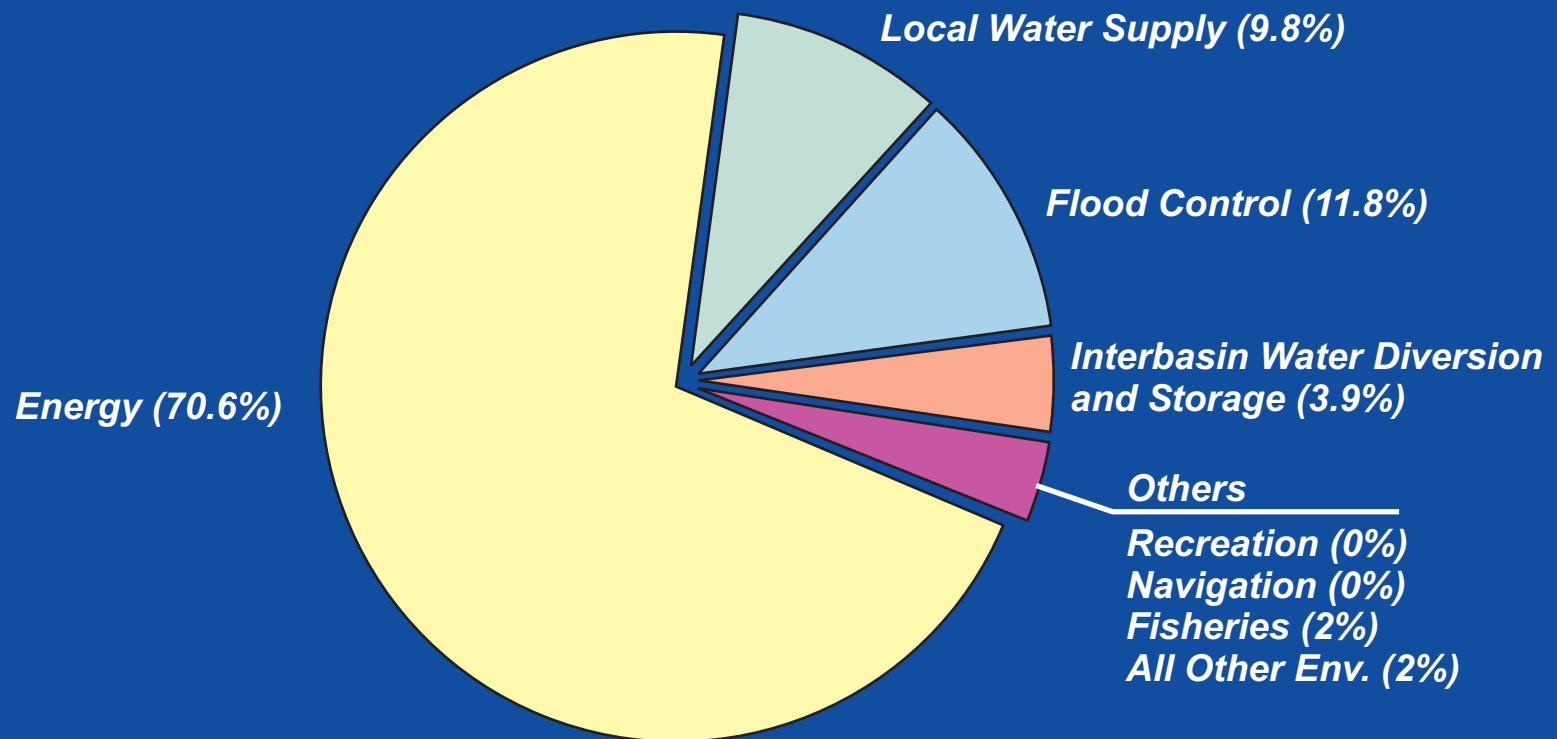


## HYDROELECTRIC OWNER'S RANKING OF PRIMARY PURPOSE AND FUNCTION



## HYDROELECTRIC OWNER'S RANKING FOR PERCENTAGE OF PURPOSE AND FUNCTION RANKINGS

(Based on Data Responses)\*

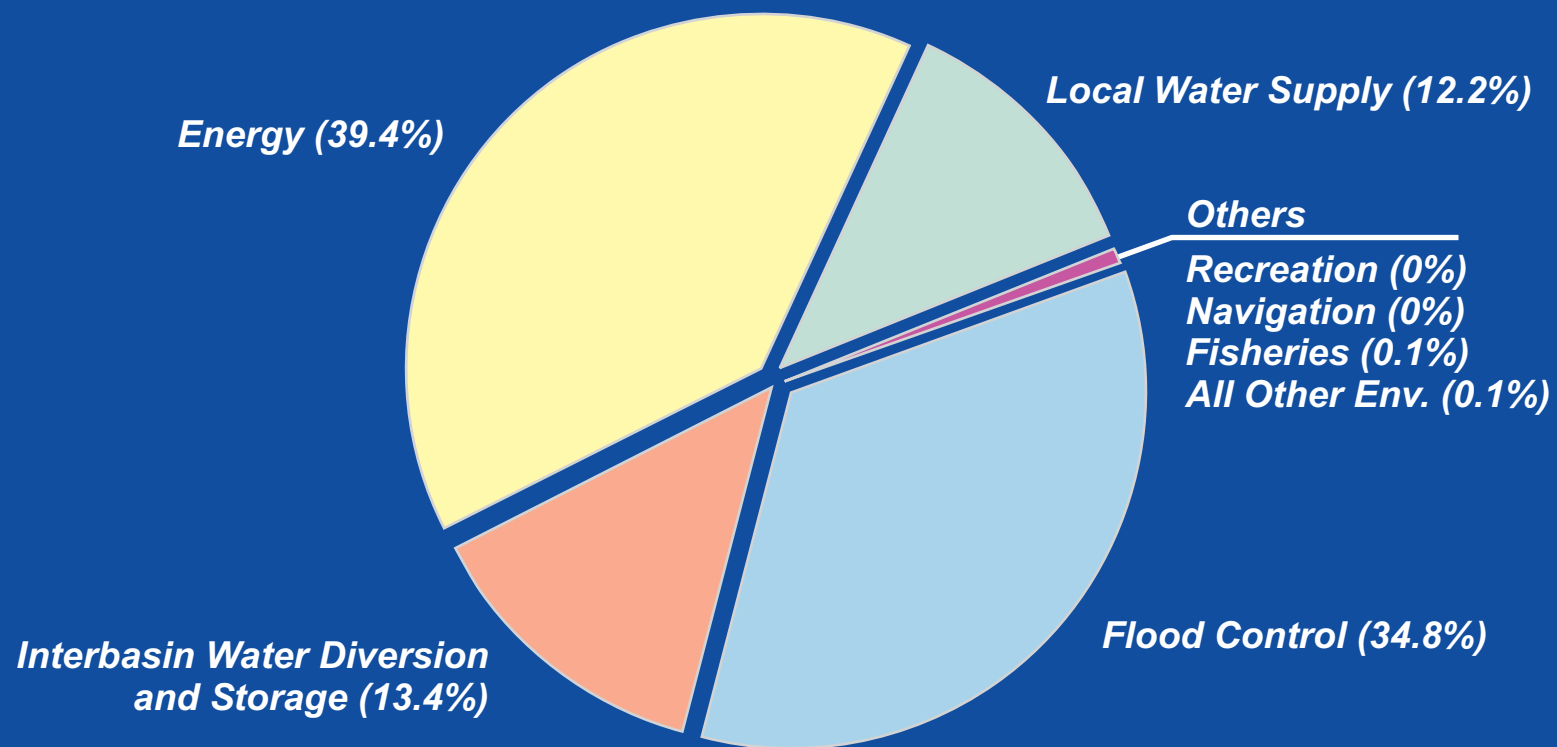


*\*Only represents 33 of 235 Plants*



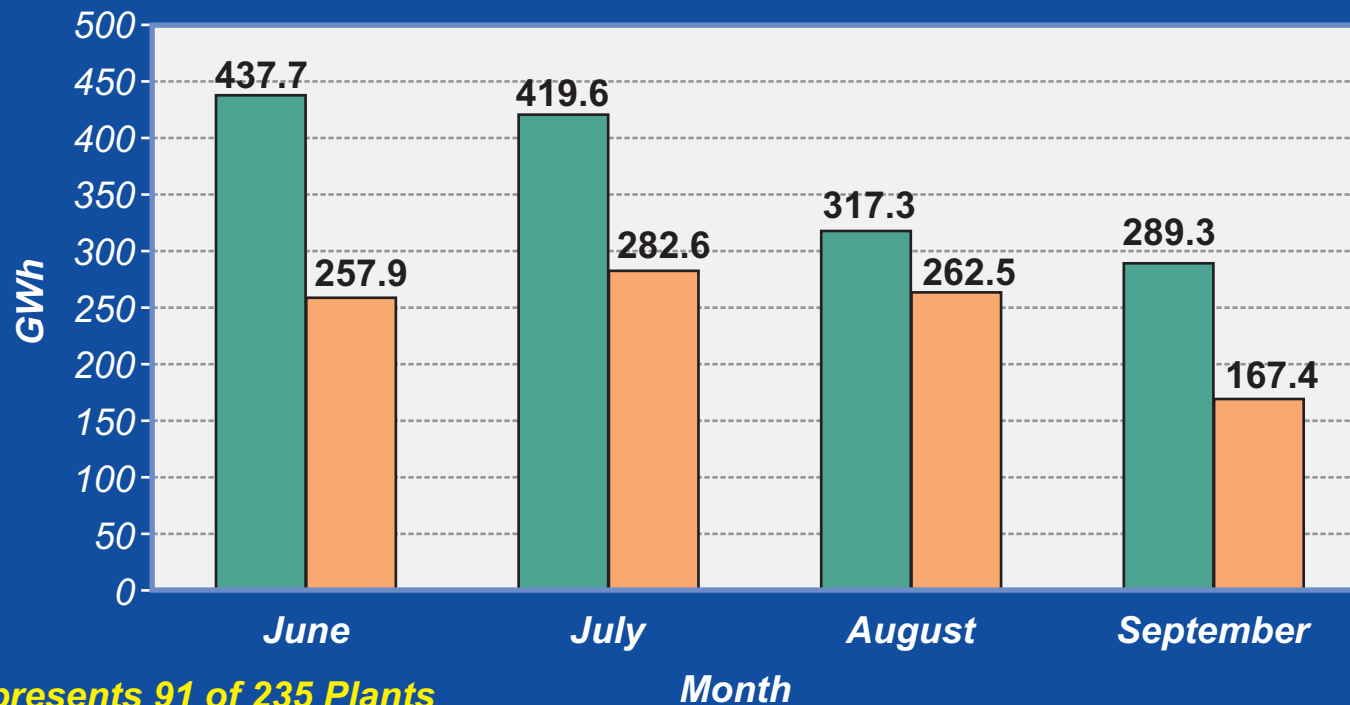
## HYDROELECTRIC OWNER'S RANKING FOR PRIMARY PURPOSE AND FUNCTION\*

(% of MW) (Based on Data Responses)

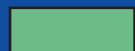


\* Represents 33 of 235 Plants

## TOTAL HISTORIC AVERAGE VS. TOTAL HISTORIC MINIMUM ENERGY PRODUCTION (Based on Data Responses)\*



\* Represents 91 of 235 Plants



Historic Average (GWh)



Historic Minimum Energy Production (GWh)

## HYDROELECTRIC PLANTS LOCATED ON HISTORIC ANADROMOUS FISH REACH

